

## [SPECIFICATIONS]

### [NAME OF INVENTION]

Method for fabricating LCD including fabrication method of a color filter by a mold

### [BRIEF EXPLANATION OF FIGURES]

FIG. 1 is a schematic exploded perspective view of a twisted nematic (TN) mode liquid crystal display device according to the related art.

FIGs. 2a to 2d are schematic perspective views showing a process of forming a color filter substrate for a liquid crystal display device according to the related art.

FIGs. 3a to 3d are schematic views showing a red color filter pattern according to an embodiment of the present invention.

FIG. 4a to 4d are schematic perspective views showing a process of forming a green color filter pattern according to an embodiment of the present invention.

FIGs. 5a to 5c are schematic perspective views showing a process of forming a blue color filter pattern according to an embodiment of the present invention.

FIG. 6 is a schematic cross-sectional view of a liquid crystal display device having a color filter layer formed through a method according to an embodiment of the present invention.

\* Explanation of major parts in the figures \*

100: substrate

200: mold

A: groove

## [DETAILED DESCRIPTION OF INVENTION]

### [OBJECT OF INVENTION]

### [TECHNICAL FIELD OF THE INVENTION AND PRIOR ART OF THE FIELD]

The present invention relates to liquid crystal display device, and more particularly, to a method of forming a color filter layer for a liquid crystal display device.

In general, a liquid crystal display device uses the optical anisotropy and polarization properties of liquid crystal molecules to produce an image. The long thin shapes of the liquid crystal can be aligned to have an orientation in a specific direction. The alignment direction of the liquid crystals can be controlled by an applied electric field.

In other words, as an applied electric field changes, so does the alignment of the liquid crystal molecules. Due to the optical anisotropy of the liquid crystal, the refraction of incident light depends on the alignment direction of the liquid crystal molecules. Thus, by properly controlling an electric field applied to a group of liquid crystal molecules in respective pixels, a desired image can be produced by diffracting light.

An active matrix LCD (AM-LCD) that has a matrix of pixels each having a thin film transistor (TFT) and pixel electrode has been the subject of significant research and development because of their high resolution and superiority in displaying moving images.

Structure of a liquid crystal panel will be illustrated with referring to FIG. 1 hereinafter.

FIG. 1 is a schematic exploded perspective view of a twisted nematic (TN) mode liquid crystal display device according to the related art.

In FIG. 1, a liquid crystal display device 10 includes a first substrate 20 having a thin film transistor (TFT) "T" and array lines 22 and 24, a second substrate 50 having a color filter

54a, 54b and 54c and a black matrix 52, and a liquid crystal layer 80 interposed between the first and second substrates 20 and 50.

The array lines include a gate line 22 and a data line 24 crossing the gate line 22 to define a pixel region "P." The TFT "T" includes a gate electrode 26 connected to the gate line 22, an active layer 28, a source electrode 30 connected to the data line 24, a drain electrode 32 spaced apart from the source electrode 30.

A transparent pixel electrode 34 connected to the drain electrode 32 is formed in the pixel region "P."

The black matrix 52 corresponding to the gate line 22, the data line 24 and the TFT "T" is formed on the second substrate 50. The second substrate 50 faces and is spaced apart from the first substrate 20. The black matrix 52 shielding light from exterior is formed of one of an opaque metal and an opaque resin.

The red, green and blue color filter patterns 54a, 54b and 54c are sequentially formed to correspond to the pixel region "P" where the black matrix 52 is not formed.

The red color filter pattern 54a is formed by coating, exposing and developing photosensitive resin. The green and blue color filter patterns 54b and 54c are formed by similar processes.

A transparent common electrode 56 is formed on the black matrix 52 and the color filter patterns 54a, 54b and 54c.

A first linear polarizing plate 85 having a first polarization axis "C1" is formed outside the first substrate 20 and a second linear polarizing plate 90 having a second polarization axis "C2" perpendicular to the first polarization axis "C1" is formed outside the second substrate 50.

A longitudinal electric field is induced perpendicularly between the pixel electrode 34 and the common electrode 56 by voltages applied to the pixel electrode 34 and the common electrode 56. Since the alignment of the liquid crystal layer 80 is changed according to the longitudinal electric field, light transmittance of the liquid crystal layer 80 is also changed. The light passes through the liquid crystal layer 80 and the color filter layer 54, thereby desired color images obtained.

The color filter patterns 54a, 54b and 54c may be formed by various methods including, for example, an electro-deposition method, a dyeing method and a pigment dispersion method. In the electro-deposition method, a color filter pattern is formed on an electrode using an electrochemical reaction. The electro-deposition method has superiority in large-sized LCD devices and a low consumption of materials. However, the color filter pattern formed through the electro-deposition method has a great deviation in property according to process condition.

In the dyeing method, a color filter pattern is formed by dyeing a dyeable resin. The color filter pattern formed through the dyeing method has low reliability for ultraviolet (UV) light and chemicals.

Accordingly, the pigment dispersion method is more commonly used. In the pigment dispersion method, a color filter pattern is formed by coating and exposing a material where polyimidic pigments are dispersed. The pigments are insoluble in the solvent.

Among methods of forming a color filter pattern, a method using pigment dispersion will be illustrated with referring to drawings hereinafter.

FIGs. 2a to 2d are schematic perspective views showing a process of forming a color filter substrate for a liquid crystal display device according to the related art.

In FIG. 2a, a black matrix 52 is formed on a substrate 50 having red, green and blue pixel regions "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>." The black matrix 52 corresponds to borders between the pixel regions.

The black matrix 52 is formed of one of chromium (Cr) and opaque resin. A double layer of chromium/chromium oxide (Cr/CrO<sub>x</sub>) is also used for the black matrix 52.

In FIG. 2b, a red resist layer 53 is formed on an entire surface of the substrate 50 having the black matrix 52 by coating a photosensitive color resist including red pigment. The photosensitive color resist is a negative type where a portion exposed to light remains after development.

Even though not shown in FIG. 2b, a mask having a transmissive portion and a shielding portion is disposed over the red resist layer 53. The transmissive portion corresponds to the red pixel region "P<sub>R</sub>." Light is irradiated onto the red resist layer 53 through the transmissive portion of the mask and then the red resist layer 53 is developed.

In FIG. 2c, a red color filter pattern 54a corresponding to the red pixel region "P<sub>R</sub>" is formed on the black matrix 52.

The red color filter pattern 54a is cured with heat in subsequent process.

In FIG. 2d, green and blue color filter patterns 54b and 54c are formed to correspond to the green and blue pixel regions "P<sub>G</sub>" and "P<sub>B</sub>," respectively, by repeating a process similar to the process shown in FIG. 2a to 2c.

The color filter patterns 54a, 54b and 54c may have one of a stripe shape and a mosaic shape.

The red, green and blue color filter pattern patterns 54a, 54b and 54c are formed by repeating steps of coating, exposing and developing.

The steps of exposing and developing are referred to as a photolithographic process. A resist layer is exposed using an exposing apparatus and a mask and developed to obtain a color filter pattern.

For example, a color filter pattern is formed through a lens projection exposing method. In the lens projection exposing method, a resist layer is exposed moving a substrate and a mask sequentially in a stepping method to obtain a color filter pattern. Since the mask and a stage having the substrate thereon sequentially move, a plurality of same patterns are formed on the substrate with one mask.

However, since one large pattern is formed using several masks having a pattern corresponding to a portion of the large pattern, each mask for the stepping method has a margin for misalignment. This margin reduces an effective area of the mask.

Moreover, as patterns become more minute, the exposing apparatus including lenses and photo becomes more expensive.

#### [TECHNICAL SUBJECT OF INVENTION]

To solve the above problems, an object of the present invention is to provide a method of forming a color filter pattern not through a photolithographic process but through a soft lithographic process.

The most important element for a soft lithographic process is a stamp or a mold having elasticity.

The stamp or the mold is a means for forming a pattern on a substrate.

The present invention uses a PDMS (polydimethylsiloxane) mold as a means for forming a pattern and provides a process of forming a color filter pattern using a capillary force.

In a method of forming a color filter pattern according to the present invention, a plurality of grooves having the same shape as the color filter pattern are formed on a PDMS mold.

The PDMS mold is attached to a substrate such that the plurality of grooves face the substrate.

Next, when a color resin having a relatively small viscosity is dropped onto a side opening of each PDMS mold, the color resin is injected between the PDMS mold and the substrate to form the color filter pattern.

Since the method of forming a color filter pattern does not use an exposure apparatus and a development step, production cost is reduced and fabrication time is reduced.

In addition, a large sized liquid crystal display device having a high resolution is obtained.

#### [CONSTRUCTION AND OPERATION OF INVENTION]

To achieve these and other objects and in accordance with the purpose of the present invention, as embodied and broadly described, a method of forming a color filter includes: defining first, second and third color pixels corresponding to first, second and third colors, respectively, on a substrate; forming a first color filter pattern on the substrate by attaching a first mold having a first groove to the substrate and injecting a first color resin into the first groove, the first groove corresponding to the first pixel; forming a second color filter pattern on the substrate by attaching a second mold having a second groove to the substrate and injecting a second color resin into the second groove, the second groove corresponding to the first and second pixels; and forming a third color filter pattern on the substrate by attaching a

third mold having a third groove to the substrate and injecting a third color resin into the third groove, the third groove corresponding to the first, second and third pixels.

The first color resin is injected through a side opening of the first groove, the second color resin is injected through a side opening of the second groove, and the third color resin is injected through a side opening of the third groove.

The method further comprises: curing the first, second and third color filter patterns with one of heat and light; and detaching the first, second and third molds from the substrate.

The first mold, the second mold and the third mold include polydimethylsiloxane (PDMS).

The second groove includes the first color filter pattern when the second groove is attached to the substrate.

The third groove includes the first and second color filter patterns when the third groove is attached to the substrate.

The first, second and third color filter patterns have a stripe shape extending along one direction.

The method further comprises forming a black matrix over the first, second and third color filter patterns.

The first, second and third color filter patterns correspond to red, green and blues colors.

In another aspect, a method of fabricating a liquid crystal display device includes: defining first, second and third color pixels corresponding to first, second and third colors, respectively, on first and second substrates; forming a first color filter pattern on the first substrate by attaching a first mold having a first groove to the first substrate and injecting a first color resin into the first groove, the first groove corresponding to the first pixel; forming

a second color filter pattern on the first substrate by attaching a second mold having a second groove to the first substrate and injecting a second color resin into the second groove, the second groove corresponding to the first and second pixels; and forming a third color filter pattern on the first substrate by attaching a third mold having a third groove to the first substrate and injecting a third color resin into the third groove, the third groove corresponding to the first, second and third pixels; forming a transparent common electrode on the first, second and third color filter patterns; forming a gate line and a data line on the second substrate, the gate line and the data line crossing each other to define a pixel region; forming a switching element at a crossing of the gate line and the data line; forming a pixel electrode in the pixel region, the pixel electrode connected to the switching element; and attaching the first and second substrates such that the pixel electrode faces the common electrode.

In another aspect, a means for forming a color filter pattern includes a first mold having a first groove corresponding to a first pixel; a second mold having a second groove corresponding to the first pixel and a second pixel; and a third mold having a third groove corresponding to the first pixel, the second pixel and a third pixel.

Hereinafter, reference will now be made in detail to the embodiment of the present invention, example of which is illustrated in the accompanying drawings.

-- EMBODIMENT --

A method of forming a color filter pattern according to the present invention uses a PDMS mold as a soft lithographic process.

Hereinafter, a fabrication process of a color filter pattern will be illustrated with referring to drawings.

FIGs. 3a to 3d, 4a to 4d and 5a to 5c are schematic cross-sectional views showing a process of forming a color filter substrate according to an embodiment of the present invention.

FIGs. 3a to 3d are schematic views showing a red color filter pattern according to an embodiment of the present invention.

In FIG. 3a, a first mold 200 is disposed to contact a substrate 100 having red, green and blue pixel regions "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>." The first mold 200 may be transparent and may be formed of elastomeric polymer such as polydimethylsiloxane (PDMS). The first mold 200 includes a first groove "A" covered by the substrate 100. The first groove "A" corresponds to the red pixel region "P<sub>R</sub>."

In FIG. 3b, a red color resin 102 is disposed to contact one end of the first mold 200. In other words, the red color resin 102 contacts a side opening of the first groove "A."

In FIG. 3c, the red color resin 102 is injected into a first channel between the first groove "A" and the substrate 100 by a capillary force. Accordingly, the first channel between the first groove "A" and the substrate 100 is gradually filled up with the red color resin 102.

A time for filling up the first channel with the red color resin 102 may be determined by a property of the color resin and a structure of the first channel according to a following equation.

$$t = (2\eta z^2)/(R\gamma_{\text{polymer/air}}\cos\theta)$$

, where z is a length of the first channel, t is a time for filling up the first channel with the red color resin,  $\eta$  is a viscosity of the red color resin, R is a hydraulic radius of the red color resin,  $\gamma_{\text{polymer/air}}$  is a interface free energy (surface tension) between the red color resin and air, and  $\theta$  is a contact angle between the red color resin and the first mold.

After filling up the first channel with the red color resin 102, the red color resin 102 may be cured with heat or light.

For example, when the red color resin 102 is a photosensitive resin, light such as ultra violet (UV) is irradiated onto the red color resin 102 through the first mold 200.

Since the first mold 200 is formed of transparent elastomeric polymer such as PDMS having a refractive index of about 1.4, light from a light source over the first mold 200 may be irradiated onto the red color resin 102 through the first mold 200.

When the red color resin 102 is a heat-curable resin, the red color resin 102 is cured through a heat treatment.

After curing the red color resin 102 in the first channel, the first mold 200 is detached from the substrate 100.

In FIG. 3d, a red color filter pattern 104 corresponding to the red pixel region "P<sub>R</sub>" is obtained by detaching the first mold 200 (of FIG. 3c) from the substrate 100. Since the red color filter pattern 104 is formed by filling the first channel (of FIG. 3c) with the red color resin 102 (of FIG. 3c), a volume of the first channel (of FIG. 3c), i.e., the first groove "A" (of FIG. 3c) is substantially the same as a volume of the red color filter pattern 104.

FIG. 4a to 4d are schematic perspective views showing a process of forming a green color filter pattern according to an embodiment of the present invention.

In FIG. 4a, a second mold 202 is disposed to contact the substrate 100 having the red color filter pattern 104. The second mold 202 may be transparent and may be formed of elastomeric polymer such as polydimethylsiloxane (PDMS).

The second mold 202 includes a second groove "A'" covered by the substrate 100. The second groove "A'" corresponds to the red and green pixel regions "P<sub>R</sub>" and "P<sub>G</sub>." As a result, the second groove "A'" constitutes a second channel corresponding to the green pixel

region "P<sub>G</sub>" with the red color filter pattern 104 and the substrate 100. In other words, the second groove "A'" includes the red color filter pattern 104 as a wall and the second channel for a green color filter pattern.

In FIG. 4b, a green color resin 106 is disposed to contact one end of the second mold 202. In other words, the green color resin 106 contacts a side opening of the second groove "A'."

In FIG. 4c, the green color resin 106 is injected into the second channel constituted by the second groove "A'," the red color filter pattern 104 and the substrate 100 by a capillary force. Accordingly, the second channel is gradually filled up with the green color resin 106. A time for filling up the second channel with the green color resin 106 may be determined by a property of the color resin and a structure of the channel. After filling up the second channel with the green color resin 106, the green color resin 106 may be cured with heat or light.

In FIG. 4d, a green color filter pattern 108 corresponding to the green pixel region "P<sub>G</sub>" is obtained by detaching the second mold 202 (of FIG. 4c) from the substrate 100.

FIGs. 5a to 5c are schematic perspective views showing a process of forming a blue color filter pattern according to an embodiment of the present invention.

In FIG. 5a, a third mold 204 is disposed to contact the substrate 100 having the red and green color filter patterns 104 and 108. The third mold 204 may be transparent and may be formed of elastomeric polymer such as polydimethylsiloxane (PDMS).

The third mold 204 includes a third groove "A'" covered by the substrate 100. The third groove "A'" corresponds to the red, green and blue pixel regions "P<sub>R</sub>," "P<sub>G</sub>," and "P<sub>B</sub>."

As a result, the third groove "A'" constitutes a third channel corresponding to the blue pixel region "P<sub>B</sub>" with the red color filter pattern 104, the green color filter pattern 108 and

the substrate 100. In other words, the third groove "A3" includes the red color filter pattern 104 as a wall, the green color filter pattern 108 and the third channel for a blue color filter pattern.

In FIG. 5b, a blue color resin 110 is disposed to contact one end of the third mold 204. In other words, the blue color resin 110 contacts a side opening of the third groove "A".

Even though not shown in FIG. 5b, the blue color resin 110 is injected into the third channel constituted by the third groove "A", the red color filter pattern 104, the green color filter pattern 108 and the substrate 100 by a capillary force. Accordingly, the third channel is gradually filled up with the blue color resin 110. A time for filling up the third channel with the blue color resin 110 may be determined by a property of the color resin and a structure of the channel.

After filling up the third channel with the blue color resin 110, the green color resin 110 may be cured with heat or light.

In FIG. 5c, a blue color filter pattern 112 corresponding to the blue pixel region "P<sub>B</sub>" is obtained by detaching the third mold 204 (of FIG. 5b) from the substrate 100 and a color filter layer 120 including red, green and blue color filter patterns 104, 108 and 112 is completed. The red, green and blue color filter patterns 104, 108 and 112 having a stripe shape are alternately formed on an entire surface of the substrate 100.

The color purity of the color filter layer 120 may be easily changed according to design. In addition, even though the method of forming the color filter layer 120 for a liquid crystal display device is illustrated, the method of forming the color filter layer 120 according to the present invention may be applied to the other devices including a color filter layer.

Moreover, even though not shown in figures, the red, green and blue color filter patterns may be formed to have different thickness from each other by molds having heights of their grooves different from each other.

FIG. 6 is a schematic cross-sectional view of a liquid crystal display device having a color filter layer formed through a method according to an embodiment of the present invention.

In FIG. 6, a liquid crystal display (LCD) device 400 includes first and second substrates 100 and 300 facing and spaced apart from each other, and a liquid crystal layer "LC" interposed therebetween.

The first and second substrates 100 and 300 include red, green and blue pixel regions "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>."

A gate line (not shown), a data line 314 and a thin film transistor (TFT) "T" connected to the gate line and the data line 314 are formed on an inner surface of the second substrate 300 in each pixel region "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>."

The TFT "T" includes a gate electrode 302 connected to the gate line, an active layer 306, a source electrode 310 connected to the data line 314 and a drain electrode 312 spaced apart from the source electrode 310.

A transparent pixel electrode 316 is formed to contact the drain electrode 312 in each pixel region "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>."

A black matrix 101 is formed on an inner surface of the first substrate 100 to correspond to borders between the pixel regions "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>." Red, green and blue color filter patterns 104, 108 and 112 are formed on the black matrix 101 through a method using molds of elastomeric polymer such as polydimethylsiloxane (PDMS). The red, green

and blue color filter patterns 104, 108 and 112 correspond to the red, green and blue pixel regions "P<sub>R</sub>," "P<sub>G</sub>" and "P<sub>B</sub>," respectively.

A common electrode 114 is formed on the color filter layer 120.

In an LCD device according to the present invention, since a color filter pattern is formed through a soft lithographic process using a mold of an elastomeric polymer such as PDMS, a total process of forming the LCD device is simplified.

The soft lithographic process using a mold of an elastomeric polymer may be used not only for an LCD device but also for the other device such as electroluminescent display device.

In addition, a color filter layer including color filter patterns having thickness different from each other may be easily formed through a soft lithographic process using a mold of an elastomeric polymer such as PDMS.

In a plane view, a color filter pattern formed through a soft lithographic process using a mold of an elastomeric polymer such as PDMS may not have a stripe shape but also one of a zigzag shape and a round shape.

#### [EFFECT OF INVENTION]

First, since a color filter layer is formed through a soft lithographic process using a mold of an elastomeric polymer such as PDMS without using an exposing apparatus, a production cost is reduced.

Second, since a process of forming a color filter layer is simplified, a process time is reduced and a production yield is improved.

Third, since a color filter layer is formed to have a length up to about 2 meters using a capillary force, a soft lithographic process using a mold of an elastomeric polymer such as PDMS may be applied to a large-sized LCD device having high resolution.

## [RANGE OF CLAIMS]

### [CLAIM 1]

A method of forming a color filter, comprising:

defining first, second and third color pixels corresponding to first, second and third colors, respectively, on a substrate;

forming a first color filter pattern on the substrate by attaching a first mold having a first groove to the substrate and injecting a first color resin into the first groove, the first groove corresponding to the first pixel;

forming a second color filter pattern on the substrate by attaching a second mold having a second groove to the substrate and injecting a second color resin into the second groove, the second groove corresponding to the first and second pixels; and

forming a third color filter pattern on the substrate by attaching a third mold having a third groove to the substrate and injecting a third color resin into the third groove, the third groove corresponding to the first, second and third pixels.

### [CLAIM 2]

The method according to claim 1, wherein the first color resin is injected through a side opening of the first groove, the second color resin is injected through a side opening of the second groove, and the third color resin is injected through a side opening of the third groove.

### [CLAIM 3]

The method according to claim 2, further comprising:

curing the first, second and third color filter patterns with one of heat and light; and  
detaching the first, second and third molds from the substrate.

[CLAIM 4]

The method according to claim 1, wherein the first mold, the second mold and the third mold include polydimethylsiloxane (PDMS).

[CLAIM 5]

The method according to claim 1, wherein the second groove includes the first color filter pattern when the second groove is attached to the substrate.

[CLAIM 6]

The method according to claim 1, wherein the third groove includes the first and second color filter patterns when the third groove is attached to the substrate.

[CLAIM 7]

The method according to claim 1, wherein the first, second and third color filter patterns have a bar shape extending along one direction.

[CLAIM 8]

The method according to claim 1, further comprising forming a black matrix over the first, second and third color filter patterns.

[CLAIM 9]

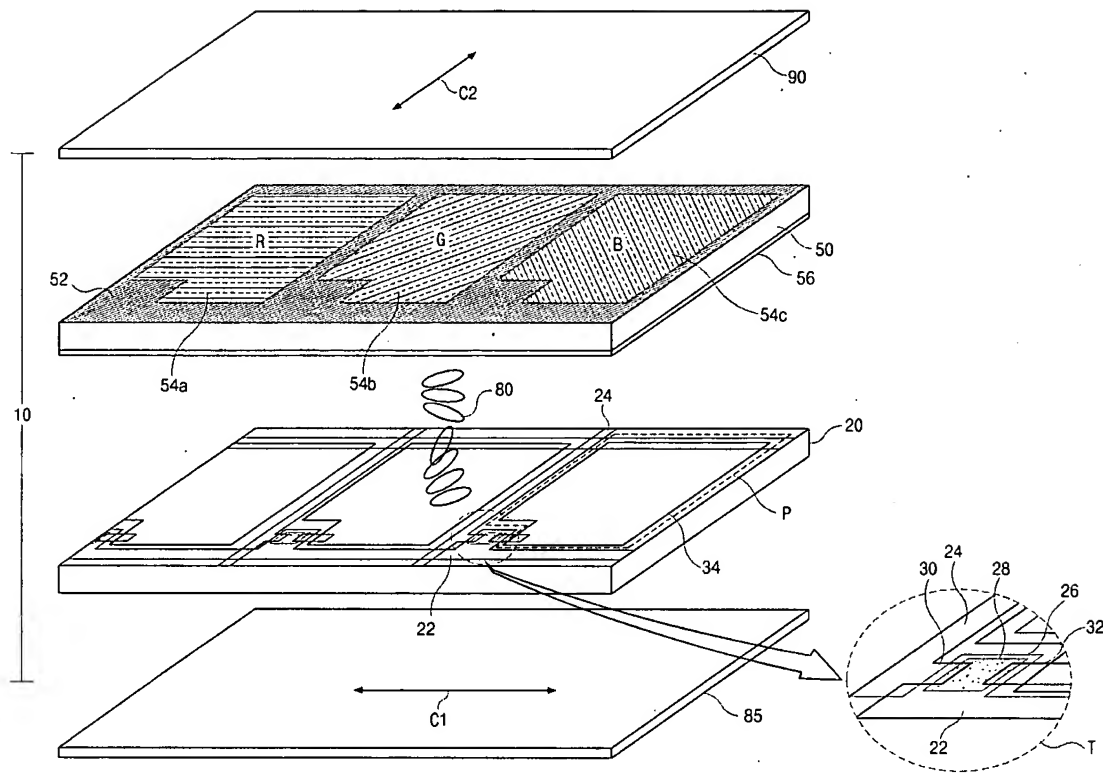
The method according to claim 1, wherein the first, second and third color filter patterns correspond to red, green and blues colors.

[CLAIM 10]

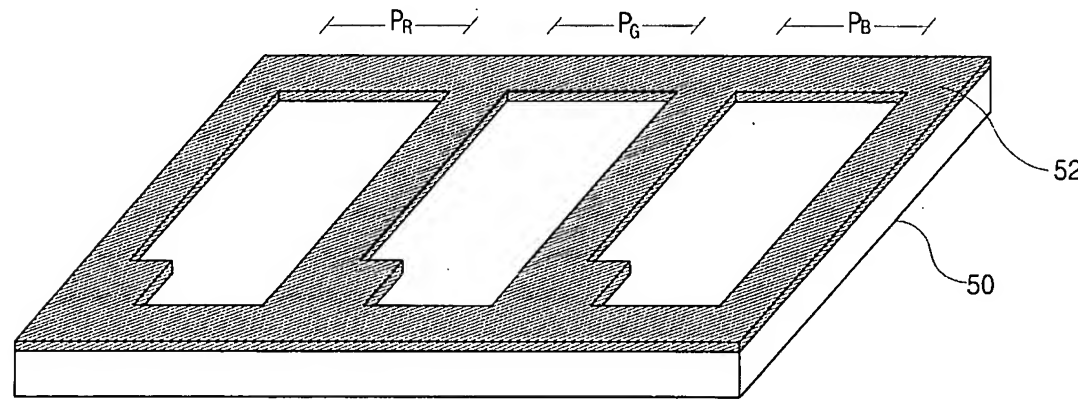
The method according to claim 1, wherein the first, second and third color filter patterns have one of a round shape and a zigzag shape.

[DRAWINGS]

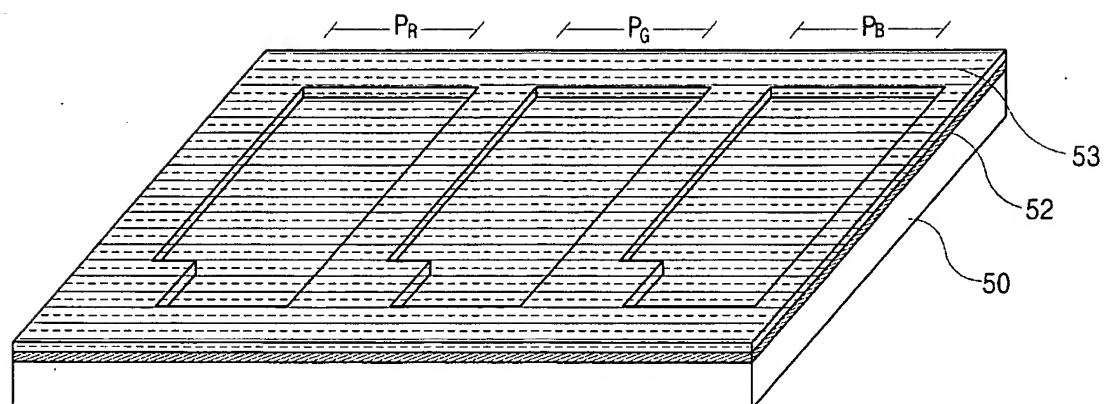
【Fig 1】



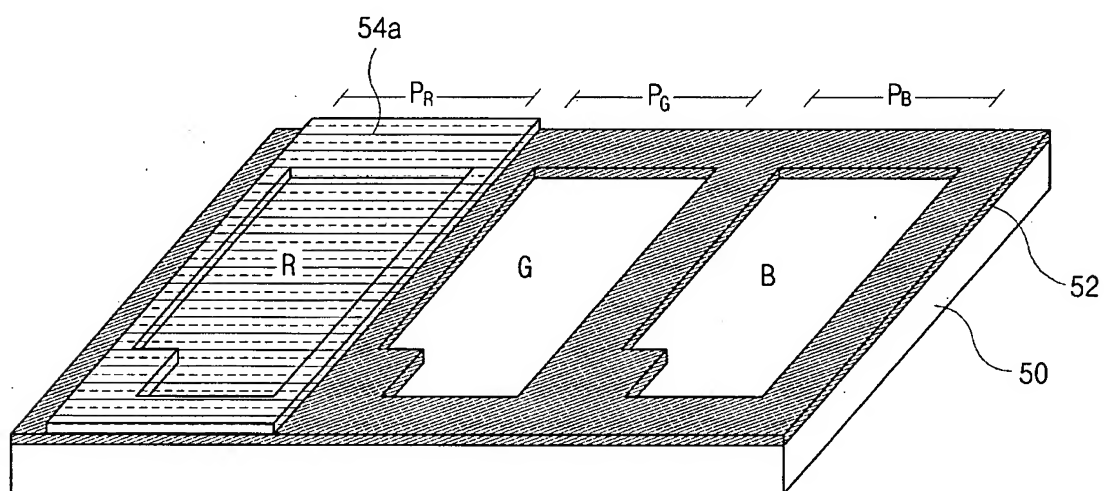
【Fig 2a】



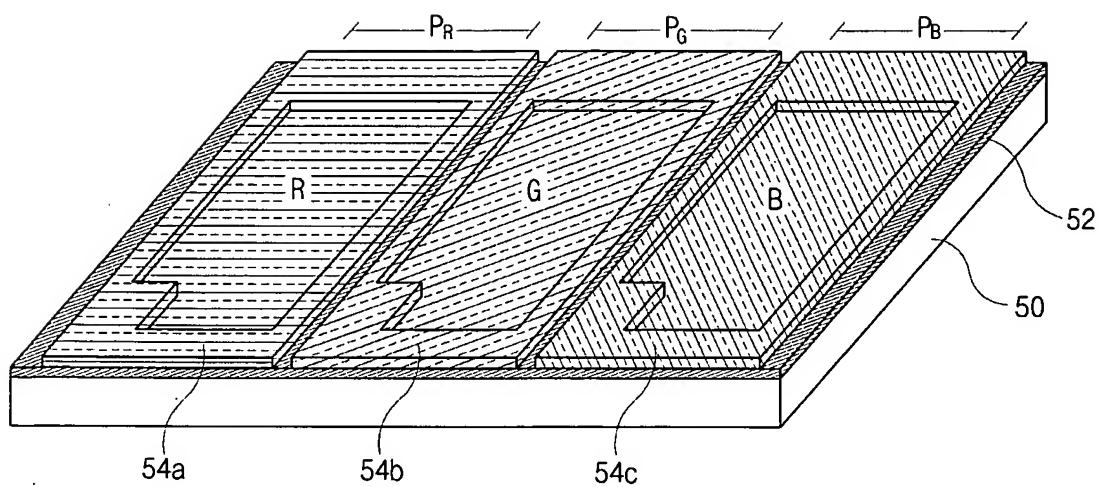
【Fig 2b】



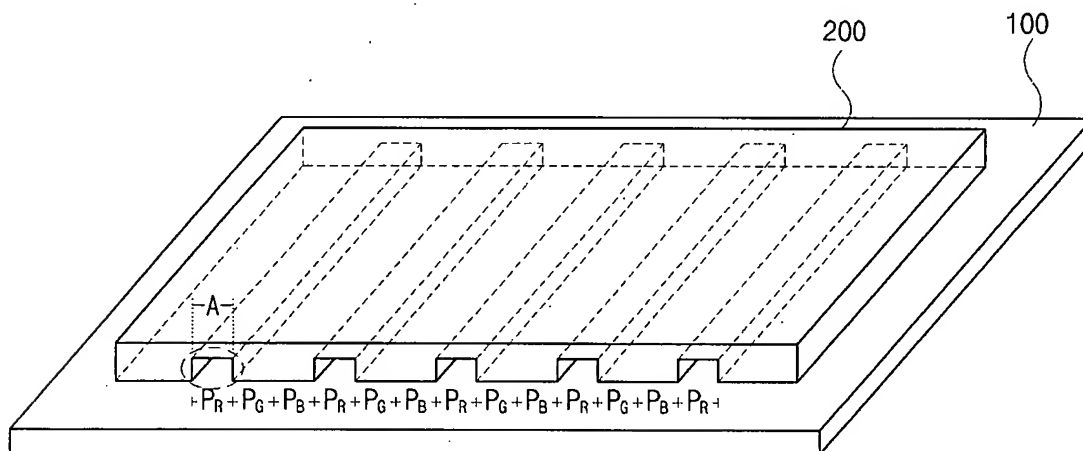
【Fig 2c】



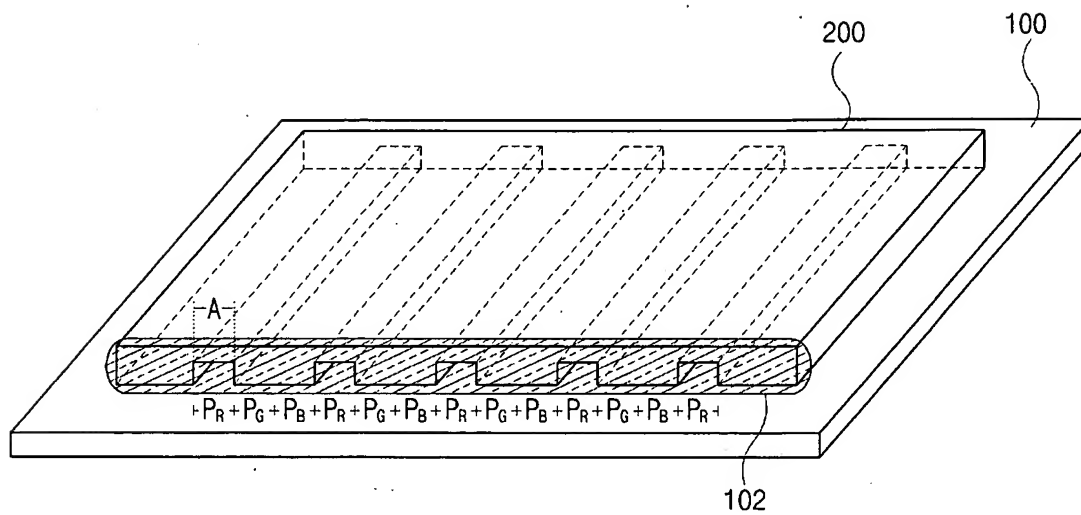
【Fig 2d】



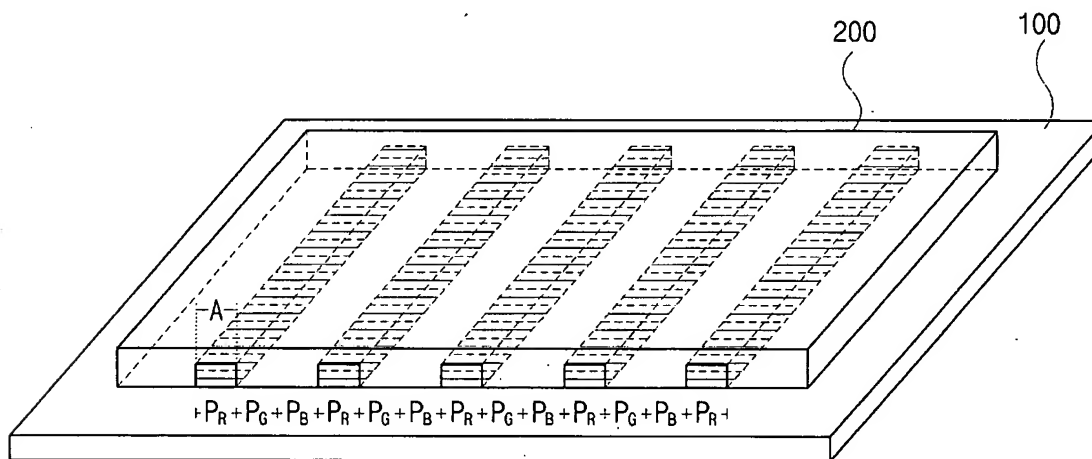
【Fig 3a】



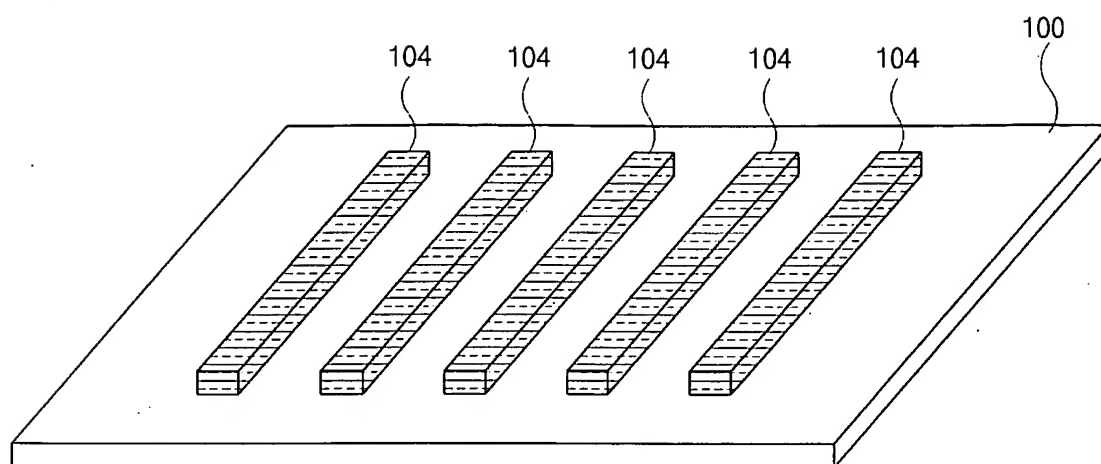
【Fig 3b】



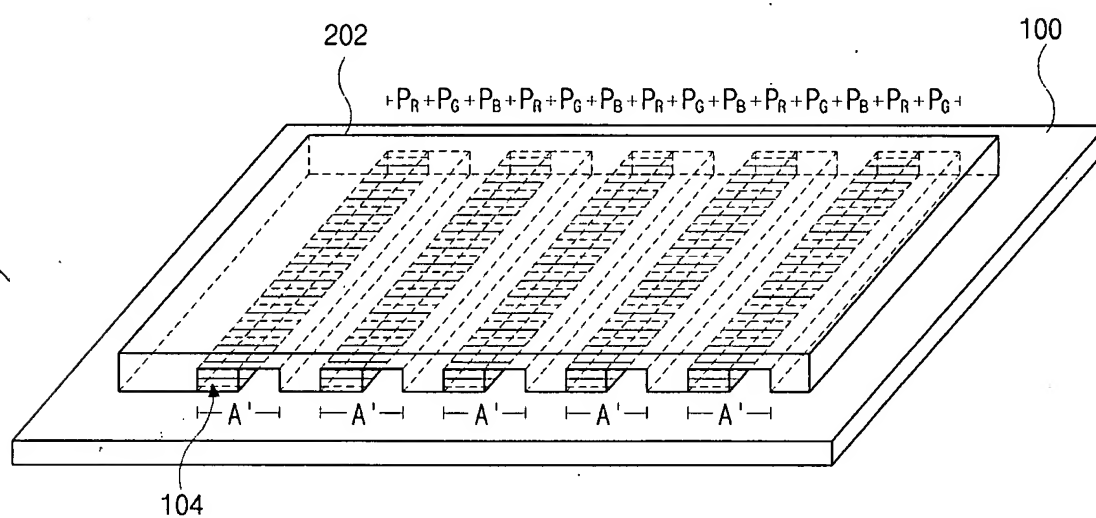
【Fig 3c】



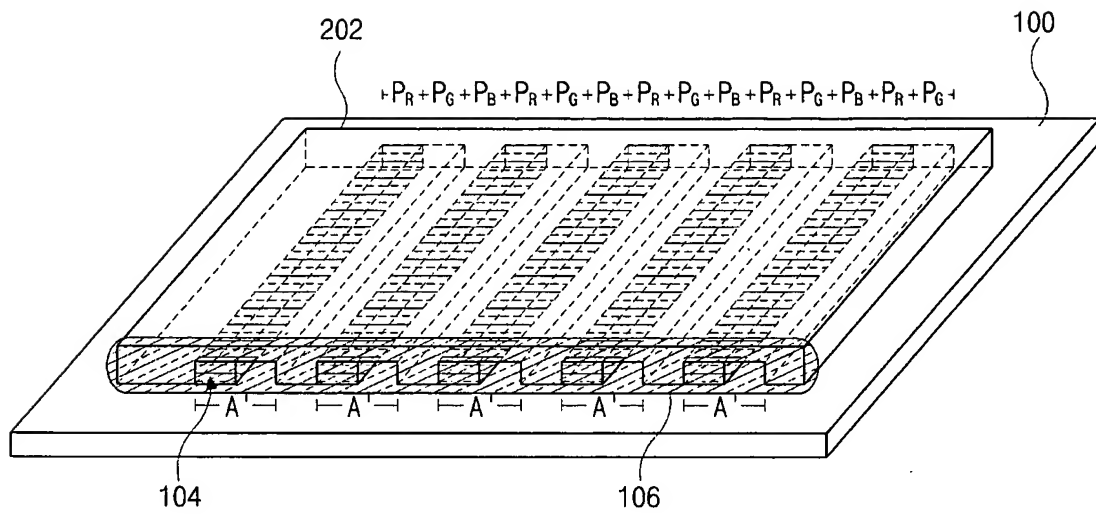
【Fig 3d】



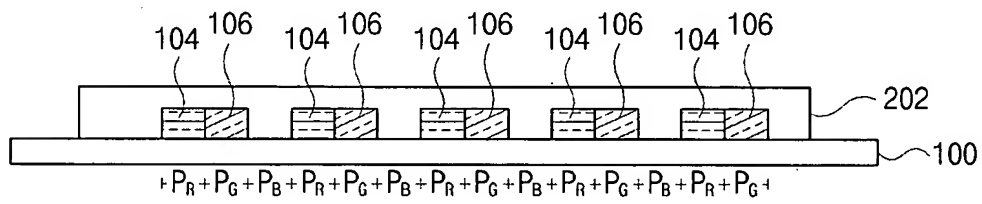
【Fig 4a】



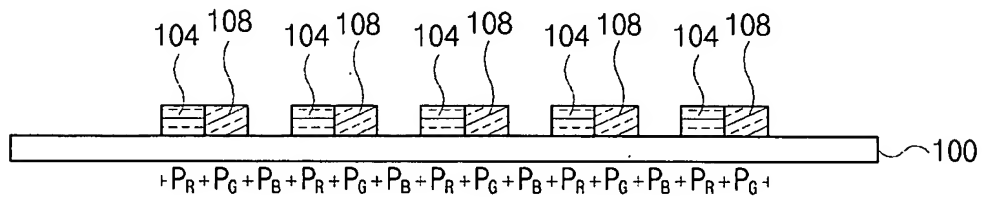
【Fig 4b】



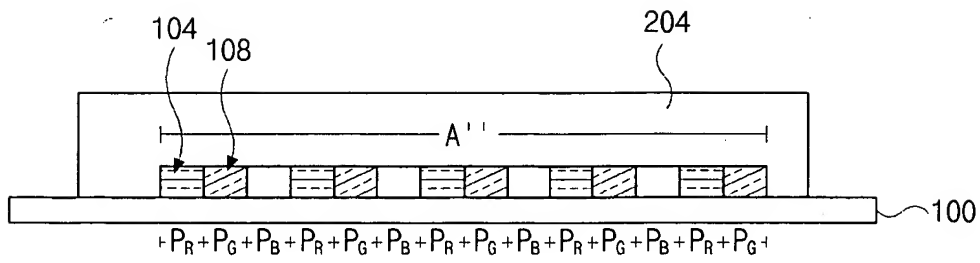
【Fig 4c】



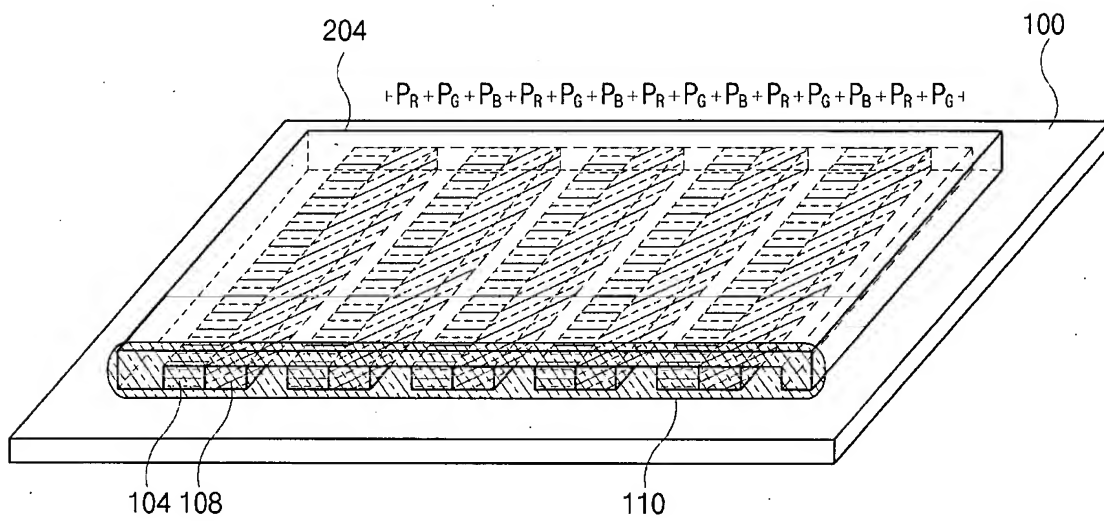
【Fig 4d】



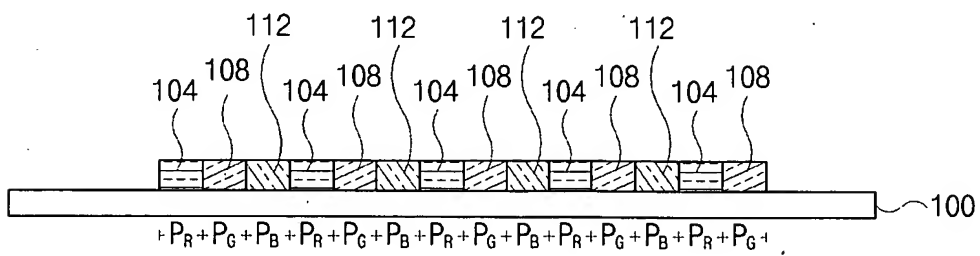
【Fig 5a】



【Fig 5b】



【Fig 5c】



【Fig 6】

